TITLE OF INVENTION

DIAGNOSIS APPARATUS FOR INTERNAL COMBUSTION ENGINE

BACKGROUND OF THE INVENTION

[0001]   This application claims the priority of Application No. 2001-272214, filed September 7, 2001, in Japan, the disclosure of which is expressly incorporated by reference herein.

[0002]   The present invention relates to an internal combustion engine diagnosis apparatus for diagnosing a catalyst to clean up a gas exhausted from an internal combustion engine, and particularly to an internal combustion engine diagnosis apparatus for diagnosing an HC adsorption catalyst which adsorbs HC when the internal combustion engine is in low temperature, and desorbs and cleans up HC when the internal combustion engine is in high temperature.

[0003]   The exhaust gas (HC, NOx, CO) exhausted from an internal combustion engine can be cleaned up by a cleanup catalyst (ternary catalyst) arranged in an exhaust pipe. However, there has been a problem in that at starting of the internal combustion engine, HC is exhausted from the internal combustion engine until the cleanup catalyst is activated. Accordingly, a problem of reducing an amount of the exhausted HC still remains.

[0004]   Therefore, a method of reducing exhaust of HC is proposed (refer to, for example, Japanese Patent Application Laid-Open No.6-101452). The method

employs an HC adsorption catalyst having a function of adsorbing HC exhausted

from an internal combustion engine when temperature of the catalyst is low, and

desorbing and cleaning up HC as temperature of the catalyst is increased.

[0005]   FIG. 1 is a schematic diagram showing the cleanup principle of the

HC adsorption catalyst. In the HC adsorption catalyst for cleaning up the HC at

starting of the internal combustion engine, HC is adsorbed to zeolite during low

temperature, as shown in FIG.1 (a), and HC desorbed from the zeolite is oxidized

on a noble metal, as shown in FIG. 1 (b).

[0006]   Since degradation of adsorption performance of the HC adsorption

catalyst is directly connected to degradation of the exhaust gas, utilizing the

relationship between an adsorption amount of HC and an adsorption amount of

water, Patent 2,894,135 proposes an exhaust gas cleanup system for internal

combustion engine. In the exhaust gas cleanup system, an adsorbent having a

function of adsorbing HC in an exhaust gas under a given low temperature

condition and an exhaust gas cleanup catalyst having a function of cleaning up

pollution substances under a given high temperature condition are arranged in

the exhaust system of the internal combustion engine. Under the low

temperature condition before activating the exhaust gas cleanup catalyst, HC is

adsorbed to the adsorbent. Under the high temperature condition after

activating the exhaust gas cleanup catalyst, the HC adsorbed to the adsorbent is

desorbed, and the desorbed HC is cleaned up by the exhaust gas cleanup

catalyst. The proposed exhaust gas cleanup system for internal combustion

engine comprises an operating state detection means for detecting an operating state of the engine; an exhaust gas temperature detection means for detecting exhaust gas temperatures at the inlet side and the outlet side of the adsorbent; an actual supplied heat equivalent value calculation means for calculating a value equivalent to an actual amount of heat supplied to the adsorbent from the exhaust gas based on the exhaust gas temperature and the exhaust gas flow rate in the inlet side of the adsorbent during dew-point period of the exhaust gas detected based on the state of the exhaust gas temperature in the outlet side of the adsorbent; an HC adsorption total amount estimation means for estimating an total amount of HC adsorbed to the adsorbent under a given adsorption condition based on the operating state of the engine; a reference supplied heat equivalent value calculation means for calculating a value equivalent to an amount of reference supplied heat supplied to the adsorbent in non-degraded state from the exhaust gas during the dew-point period of the exhaust gas based on the estimated total amount of adsorbed HC; and a degradation degree detection means for detecting a degradation degree of the adsorbent based on the calculated reference supplied heat equivalent value and the calculated actual supplied heat equivalent value.

[0007]   Further, Japanese Patent Application Laid-Open No.11-324659 proposes a system for diagnosing a degradation state of a hydrocarbon converting efficiency of a catalyst converter including a catalyst by measuring the catalyst temperature during the activation period. The system is a

hydrocarbon converting efficiency degradation diagnosis apparatus for a catalyst converter which comprises a temperature sensor for continuously generating a first output signal expressing the catalyst temperature integrated with the catalyst converter; and a controller generating a second output signal for instructing the hydrocarbon efficiency of the catalyst converter based on variation of the catalyst temperature during the activation period.

[0008]   However, the conventional diagnosing technology has the following problems to be explained below. FIG. 2 is a schematic graph showing the relationship between adsorption rate / cleanup rate and temperature of an HC adsorption catalyst. Degradation 1 shown in FIG. 2 indicates degradation of adsorption performance caused by thermal destruction of zeolite, and degradation 2 indicates degradation of activation performance (light-off performance) caused by thermal coagulation of the noble metal. Further, the HC adsorbed to the zeolite is desorbed in the catalyst temperature range of 50°C to 250°C though it depends on the operating condition of the internal combustion engine.

[0009]   FIG. 3 shows the relationship between the amount of adsorbed HC and the amount of released or emitted HC without being cleaned up during being desorbed (the released HC amount). It can be understood from the figure that in the invention of Patent 2,894,135, the degradation in the case of degradation 1 can be judged because the amount of adsorption is reduced, but the degradation in the case of degradation 2 can not be judged because the amount of adsorption

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is not reduced. Therefore, there is possibility that the degradation of exhaust gas can not accurately detect.

[0010] On the other hand, the technology described in Japanese Patent Application Laid-Open No.11-324659 detects only the degradation of the light-off performance corresponding to the degradation 2 based on the variation of the catalyst temperature during operating period, and the heat of adsorption specific to the HC adsorption catalyst and the variation of heat capacity of the catalyst are not taken into consideration. Therefore, there is also possibility that the degradation of exhaust gas can not accurately detect.

SUMMARY OF THE INVENTION

[0011] In order to solve the above problem, an object of the present invention is to provide an internal combustion engine diagnosis apparatus which can accurately diagnose the HC cleanup performance in the HC adsorption catalyst.

[0012] That is, the first object of the present invention is to provide an internal combustion engine diagnosis apparatus which can accurately diagnose degradation of the HC adsorption catalyst. The second object of the present invention is to provide an internal combustion engine diagnosis apparatus which can diagnose the HC adsorption catalyst without being affected by a degradation state of a cleanup catalyst arranged upstream of the HC adsorption catalyst and can diagnose the upstream cleanup catalyst. Further, the third object of the

present invention is to provide an internal combustion engine diagnosis apparatus which can diagnose the HC adsorption catalyst without being affected by the operating condition of the internal combustion engine.

[0013]   In order to attain the above objects, an internal combustion engine diagnosis apparatus in accordance with the present invention basically comprises a cleanup catalyst arranged in an exhaust pipe of an internal combustion engine; and an HC adsorption catalyst arranged in parallel to and downstream of the cleanup catalyst, during high temperature period the HC adsorption catalyst desorbing and cleaning up HC desorbed during low temperature period, wherein degradation of the HC adsorption catalyst is diagnosed based on temperature of the HC adsorption catalyst while HC is being desorbed from the HC adsorption catalyst (during HC desorbing period).

[0014]   Further, other features of the internal combustion engine diagnosis apparatus in accordance with the present invention are characterized by that degradation of the HC adsorption catalyst is diagnosed based on a gradient of temperature of the HC adsorption catalyst during a period when temperature of the HC adsorption catalyst is within a range of 50°C to 250°C, and that the internal combustion engine comprises a temperature detector for detecting temperature of the HC adsorption catalyst, and degradation of the HC adsorption catalyst is diagnosed based on a detected value of the temperature detector.

[0015] Based on the structure described above, the internal combustion engine diagnosis apparatus can diagnose degradation of the HC adsorption catalyst from a condition of temperature variation of the HC adsorption catalyst when the temperature during desorbing of HC from the HC adsorption catalyst is within the range of 50°C to 250°C. That is, since the internal combustion engine diagnosis apparatus utilizes the heat of reaction at desorbing HC of the HC adsorption catalyst (the heat of reaction is decreased as the degradation is progressed), the HC cleanup performance of the HC adsorption catalyst can be accurately diagnosed, and diagnosis of the HC adsorption catalyst can be performed without being affected by the degradation state of the cleanup catalyst arranged upstream of the HC adsorption catalyst.

[0016] Further, other features of the internal combustion engine diagnosis apparatus in accordance with the present invention are characterized by that a temperature gradient during evaporating of water adsorbed to the HC adsorption catalyst is calculated, and the temperature gradient is compared with a preset diagnosis threshold, and if the temperature gradient is smaller than the diagnosis threshold, it is judged that the HC adsorption catalyst is degraded; and that a temperature gradient after evaporating of water adsorbed to the HC adsorption catalyst is calculated, and the temperature gradient is compared with a preset diagnosis threshold, and if the temperature gradient is larger than the diagnosis threshold, it is judged that the HC adsorption catalyst is degraded; and that a temperature gradient during evaporating of water adsorbed to the HC

adsorption catalyst and a temperature gradient after evaporating of water adsorbed to the HC adsorption catalyst are calculated, and a ratio of the two temperature gradients is compared with a preset diagnosis threshold, and if the temperature gradient ratio is larger than the diagnosis threshold, it is judged that the HC adsorption catalyst is degraded.

[0017]   The above-described structure of the internal combustion engine diagnosis apparatus in accordance with the present invention utilizes the fact that the temperature variation state of the HC adsorption catalyst is different between during evaporating of water adsorbed to the HC adsorption catalyst and after evaporating of the water, that is, there is a difference between the catalyst temperature variation caused by the heat of reaction of the HC catalyst desorption and the catalyst temperature variation caused by the catalyst cleanup. By employing the above-described structure, it is possible to accurately diagnose the HC adsorption catalyst.

[0018]   Further, other features of the internal combustion engine diagnosis apparatus in accordance with the present invention are characterized by that a time period that HC is being desorbed from the HC adsorption catalyst (HC desorbing time period) is measured, and if the HC desorbing time period is larger than a preset diagnosis threshold, it is judged that the HC adsorption catalyst is degraded; and that the HC desorbing time period is a period from time that temperature of the HC adsorption catalyst exceeds 50°C to time that the temperature reaches 250°C.

[0019]   Further, other features of the internal combustion engine diagnosis apparatus in accordance with the present invention are characterized by that if the desorbing time period exceeds a preset time, judgment of degradation of the HC adsorption catalyst is prohibited; and that if a cumulative value or a maximum value of a flow rate of air flowing into the internal combustion engine during the HC desorbing time period exceeds a preset value, judgment of degradation of the HC adsorption catalyst is prohibited.

[0020]   Further, other features of the internal combustion engine diagnosis apparatus in accordance with the present invention are characterized by that the diagnosis threshold is corrected based on a flow rate of air flowing into the internal combustion engine during the HC desorbing time period; and that the internal combustion engine diagnosis apparatus comprises an air flow rate measurement instrument for measuring a flow rate of air flowing into the internal combustion engine.

[0021]   Further, another feature of the internal combustion engine diagnosis apparatus in accordance with the present invention is characterized by that when the HC desorbing time period exceeds the diagnosis threshold corrected based on the flow rate of air flowing into the internal combustion engine, it is judged that the cleanup catalyst arranged upstream of the HC adsorption catalyst is degraded.

[0022]   Other objects, advantages and novel features of the present invention will become apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

[0023]   FIG. 1 is schematic views showing the cleaning-up principle of an HC adsorption catalyst under (a) a low temperature condition and (b) a high temperature condition.

[0024]   FIG. 2 is a graph showing the relationship between adsorption rate / cleanup rate and temperature of an HC adsorption catalyst.

[0025]   FIG. 3 is a graph showing patterns of normal and degraded HC adsorption catalyst.

[0026]   FIG. 4 is a diagram showing a direct injection internal combustion engine to which an embodiment of an internal combustion engine diagnosis apparatus of the present invention is applied.

[0027]   FIG. 5 is a graph showing the relationship between exhausted HC and time after starting of the engine based on the diagnosis apparatus of FIG. 4.

[0028]   FIG. 6 a graph showing the relationship between temperature during HC desorbing of the HC adsorption catalyst and time after starting of the engine based on the internal combustion engine diagnosis apparatus of FIG. 4.

[0029]   FIG. 7 is a control flowchart showing diagnosing procedure of the internal combustion engine diagnosis apparatus of FIG. 4.

[0030]   FIG. 8 is a graph showing the relationship between temperature (temperature gradient) of the HC adsorption catalyst during HC desorbing and time after starting of the engine based on the internal combustion engine diagnosis apparatus of FIG. 4.

[0031]   FIG. 9 is a control flowchart of calculating the degradation index using the temperature (temperature gradient) of the HC adsorption catalyst during HC desorbing based on the internal combustion engine diagnosis apparatus of FIG. 4.

[0032]   FIG. 10 is a control flowchart showing a portion of the degradation judgment processing of the control flowchart of FIG. 7.

[0033]   FIG. 11 is a control flowchart in which correction of diagnosis threshold is added to the degradation judgment processing of FIG. 10.

[0034]   FIG. 12 is a graph showing an example of a map for correcting the diagnosis threshold depending on the operating condition.

[0035]   FIG. 13 is a graph showing an example of a map for correcting the diagnosis threshold depending on the degradation of the catalyst.

[0036]   FIG. 14 is a control flowchart of calculating the degradation index of the pre-catalyst of the internal combustion engine diagnosis apparatus of FIG.4.

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[0037]   FIG. 15 is a graph showing the relationship between the degradation index of FIG. 14 and the operating condition.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0038]   An embodiment of an internal combustion engine diagnosis apparatus in accordance with the present invention will be described below in detail, referring to the accompanied drawings.

[0039]   FIG. 4 shows the overall outline of a direct injection internal combustion engine to which the embodiment of the internal combustion engine diagnosis apparatus is applied. The internal combustion engine 1 comprises a piston 6 and a combustion chamber 1a; and an intake pipe 14 and an exhaust pipe 15 in the upper portion of the combustion chamber 1a; and an intake valve 16 and an exhaust valve 17 in the opening portions of the intake pipe 14 and the exhaust pipe 15.

[0040]   Although the present embodiment of the diagnosis apparatus for the internal combustion engine 1 is installed as a program of an ECU 13 of the internal combustion engine, it may be installed in a microcomputer separated from the ECU 13.

[0041]   In the exhaust pipe 15 of the present embodiment, a cleanup catalyst 9 (a pre-catalyst) is arranged, and an HC adsorption catalyst 10 is arranged downstream of the cleanup catalyst 9. A temperature signal from a temperature

sensor 2 for detecting temperature of the HC adsorption catalyst 10, an oxygen concentration signal from an oxygen (an air-fuel ratio) sensor 3 attached to a position upstream of the cleanup catalyst, an air flow rate signal from an air flow rate sensor 5 provided upstream of a throttle 4 of the intake pipe 14, a rotation angle signal from a crank angle sensor 8 attached to a crank shaft 7 connected to the piston 6 and so on are input to the ECU 13.

[0042]   A fuel injection signal to an injector 11 for injecting fuel based on the input information, an ignition signal to a spark plug 12, a throttle control signal to the throttle 4 for regulating an air flow rate and so on are output from the ECU 13. There, although the direct injection internal combustion engine is shown in FIG. 4 as an example, There is no need to say that the internal combustion engine diagnosis apparatus in accordance with the present invention can be realized using a port injection internal combustion engine.

[0043]   Further, although the temperature sensor 2 is arranged at a position down stream of the catalyst, the temperature sensor 2 may be directly attached to the catalyst.

[0044]   FIG. 5 shows an example of an exhaust profile of the internal combustion engine 1 in the embodiment of FIG. 4. The HC adsorption catalyst 10 adsorbs HC before lighting-off of the pre-catalyst 9, and reduces exhaust gas by cleaning up during desorbing HC. However, as shown in FIG. 2, HC is released without being cleaned up depending on degradation of the adsorption rate and

the cleanup ratio and the operating condition, and accordingly the amount of released HC may be increased to degrade the exhaust gas as the degradation is progressed.

[0045]   FIG. 6 shows a temperature profile after starting the internal combustion engine obtained by a temperature sensor attached to a position several cm downstream of the HC adsorption catalyst 10. As shown in FIG. 6, the temperature characteristic during desorbing HC is different between a degraded catalyst and a normal (new) catalyst. The reason is that the heat of reaction (desorbed HC and water are re-adsorbed, or desorbed HC is react with oxygen) and heat capacity (varied by adsorbed HC and water) during the HC desorbing period are varied by the adsorption performance and the cleanup performance.

[0046]   Therefore, by utilizing the temperature variation during the HC desorbing period, the HC adsorption catalyst 10 can be diagnosed from the temperature during the HC desorbing period. Further, since the pre-catalyst 9 is generally activated after desorbing HC, there is no difference in heat of reaction between the degraded catalyst and the normal catalyst because HC does not flow into the HC adsorption catalyst 10 after desorbing HC. That is, in order to diagnose degradation of the HC adsorption catalyst 10 based on the temperature, it is necessary to measure the temperature during desorbing HC. In more detail, in order to diagnose based on the temperature, it is necessary to diagnose based

on a temperature range from a desorption starting temperature (50°C) to a desorption ending temperature (250°C).

[0047]   FIG. 7 is a control flowchart of degradation judgment of the HC adsorption catalyst 10 used in the present embodiment of the internal combustion engine diagnosis apparatus.

[0048]   In Step S101, it is checked whether or not the diagnosis condition holds. If the diagnosis condition to be described below holds, the processing of the steps after Step S102 is executed. If the diagnosis condition does not hold, the processing of the steps after Step S102 is not executed to complete the diagnosis.

[0049]   The diagnosis conditions of Step S101 considered are that the HC adsorption catalyst 10 is in a state capable of adsorbing HC at starting of the engine (the catalyst temperature is below a given value, or water temperature of the internal combustion engine is below a given value, or elapsed time after stopping operation of the internal combustion engine is larger than a given time), and that there is no failure in the other devices (abnormalities in the water temperature sensor, the air-fuel ratio sensor, the thermostat, the pre-catalyst and so on).

[0050]   A degradation index, to be described later, of the catalyst is calculated in Step S102, and it is judged in Step S103 whether or not a diagnosis inhibition condition holds. If the diagnosis inhibition condition, to be described below, holds, the processing of the steps after Step S104 is not executed to

complete the diagnosis. If the diagnosis inhibition condition does not hold, the processing of the steps after Step S104 is executed.

[0051]   The diagnosis inhibition conditions of Step S103 considered are that an operating condition during calculating the degradation index is within a given range (the cumulative value and the maximum value of an intake air flow rate are smaller than given values, fuel cut cumulative time is smaller than a given value and so on), and that the calculation of the degradation index is not completed.

[0052]   Because the present embodiment of the diagnosing method is particularly sensitive to the degradation of the pre-catalyst 9 and the operating condition of the engine, it is necessary to judge whether or not these conditions satisfy the given conditions.

[0053]   Next, in Step S104, degradation judgment processing, to be described later, is executed, and a degradation judgment flag is set if degradation is judged. In Step S105, if degradation is judged, according to the degradation flag in Step S104 the processing proceeds to Step S107 to execute processing at NG judgment. If not, the processing proceeds to Step S106 to execute processing at OK judgment.

[0054]   In the processing at NG judgment of Step S107, a warning light (MIL) of the internal combustion engine is put on, and the abnormal judgment record is stored in a non-volatile memory. On the other hand, in the processing

at OK judgment of Step S106, completion of the diagnosis and the normal

judgment record are stored in the non-volatile memory.

[0055]   According to the control flowchart for degradation judgment of FIG.

7, an erroneous diagnosis can be prevented by providing the diagnosis condition

of Step S101 to inhibit diagnosis under condition that the temperature of the HC

adsorption catalyst after stopping operation of the engine is high not to exert the

adsorption performance. Further, it is possible to prevent occurrence of an

erroneous diagnosis caused by a failure of another device (for example, when an

abnormality occurs in the pre-catalyst, an erroneous diagnosis may be caused

because HC always flows into the HC adsorption catalyst).

[0056]   Further, by providing the diagnosis inhibition condition of Step S103,

an erroneous diagnosis can be prevented by inhibiting the degradation judgment

when any operating condition influencing HC desorption is detected.

[0057]   FIG. 8 is a graph explaining the temperature gradient of the HC

adsorption catalyst used for calculation of the degradation index. A gradient 1

indicates a temperature gradient during evaporating water adsorbed to the

catalyst. There, the gradient 1 is affected by three heat elements. That is, one is

the exhaust heat flowing into the catalyst, another is the heat of evaporation at

evaporating the water, and the other is the heat of reaction (generated at

adsorbing and at cleaning up) of the HC desorption. The gradient 1 is strongly

correlated with the heat of reaction of the desorbing HC because an amount of

exhaust heat flowing into the catalyst during evaporating water is small and the heat of evaporation is not affected by the degradation state of the catalyst. Further explaining in detail, when the catalyst is cooled by the heat of evaporation at evaporating water, the desorbed HC is re-adsorbed or HC newly flowing into the catalyst is adsorbed to the catalyst to generate heat caused by the adsorption. Therefore, the adsorption performance of the catalyst is higher as the gradient 1 is larger, and accordingly the gradient 1 can be used as a degradation index of the HC adsorption catalyst.

[0058] On the other hand, a gradient 2 is a temperature gradient after evaporating water, and the gradient 2 rises more rapidly as the cleanup amount is smaller, on the contrary to the gradient 1. This is because the gradient 2 is caused by the exhaust gas flowing into the catalyst and the heat transfer characteristic of the catalyst, and when the cleanup amount is reduced, the difference between the catalyst temperature and the flow-in exhaust gas temperature is increased to increase the amount of transferred heat after evaporating water. Therefore, since the temperature of the catalyst rises rapidly, the degradation index can be calculated from the gradient 2.

[0059] In a new catalyst, an amount of water or HC adsorbed onto the surface of the catalyst is large, and the heat capacity is also large because zeolite is not crushed yet. This is one of reasons that the temperature rising rate of a new catalyst is moderate. There, the temperatures Tc_lo, Tc_mi and Tc_hi in FIG. 8 indicates temperature of starting HC desorption, temperature of ending

water evaporation and temperature ending HC desorption, respectively. If an initial condition of a vehicle is equal to a condition of an FTP mode test, the temperature Tc_lo is about 50°C at a position several cm downstream of the catalyst, the temperature Tc_mi is about 80°C, and the temperature Tc_hi is about 250°C.

[0060]   A method of calculating the degradation index will be described below, taking the above characteristics into consideration. FIG. 9 is a control flowchart of calculating the degradation index based on the gradient 1. In Step S201, it is judged whether or not the condition is under HC desorption and under water evaporation. If the condition holds, the processing of the steps after Step S202 is executed. If the condition does not hold, the processing of the steps after Step S202 is not executed to complete the calculation processing.

[0061]   In the concrete, Step S201 is executed by judging whether or not the catalyst temperature falls between the desorption starting temperature Tc_lo (about 50°C, to be varied a little depending on the position of the temperature sensor) determined by the catalyst performance and the water evaporation temperature Tc_mi (about 80°C, to be varied a little depending on the position of the temperature sensor).

[0062] ·   In Step S202, a case of calculating an average value of the gradient as the degradation index is shown. In the concrete, the catalyst temperature is sampled in a cycle of ST, and a gradient $\Delta T(n)$ is calculated from a difference to

the precedent value T(n-1), and the obtained gradient is summed every sampling, and the summed value is divided by number of sampling times k1. The degradation index is not limited to the average value, but another statistical reference value such as a maximum frequency value or a center value may be used.

[0063]   In Step S203, if number of sampling times k1 is larger than a preset value kl_limit, the processing proceeds to Step S204 to set degradation calculation completion flag FTICF.

[0064]   On the other hand, in Step S104 of FIG. 7, the degradation can be judged by executing the processing shown by the control flowchart of FIG. 10. In Step S301, a degradation index 1 is compared with a diagnosis threshold which is set corresponding to an exhaust gas criteria. If the degradation index is smaller than the diagnosis threshold, it is judged that the HC adsorption catalyst 10 is degraded. In Step S302, NG judgment flag FNGHCCAT is set. Further, in order to make the diagnosis accurate, it is preferable to correct the diagnosis threshold using the cumulative value or the maximum value of the air flow rate during the HC desorbing period.

[0065]   By correcting the diagnosis threshold in Step S401, for example, as shown in the control flowchart of FIG. 11 (for example, correcting based on the cumulative value of the air flow rate as shown in FIG. 12 (a), or correcting based on the maximum value of the air flow rate as shown in FIG. 12 (b)), the HC

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adsorption catalyst 10 can be diagnosed without being affected by the operating condition. Step S402 and Step S 403 of FIG. 11 are the same as Step S301 and Step S302 of FIG. 10.

[0066] Further, by correcting the diagnosis threshold based on the degradation index of the pre-catalyst 9 as shown in FIG. 13, the HC adsorption catalyst 10 can be diagnosed without being affected by the degradation of the pre-catalyst 9.

[0067] FIG. 14 shows a control flowchart of calculating the degradation index of the pre-catalyst 9. In Step S501, it is judged whether or not the catalyst is under HC desorption. If the catalyst is under HC desorption, the processing of the steps after Step S502 is executed. If the catalyst is not under HC desorption, the processing of the steps after Step S502 is not executed. In Step S502, time spent in desorption (desorption time) is measured by counter calculation. In Step S503, the degradation index is calculated from a map of desorption time and a cumulative value of air flow rate (a total amount of air flow) in-taken during the desorbing period.

[0068] FIG. 15 is a map showing the relationship between the degradation index of the pre-catalyst and the total amount of air flow. By making the degradation index of the pre-catalyst larger as the desorption time is longer, and by making the degradation index larger as the total amount of air flow is larger

when the desorption time is kept constant, an effect of the operating condition can be corrected.

[0069]   Although the embodiment of the present invention has been described in detail, it is to be understood that the present invention is not limited to the above embodiment, and that various changes in design may be resorted to without departing from the spirit of the present invention described in what is claimed is.

[0070]   Although diagnosing method based on the gradient 1 of FIG. 8 has been described, the degradation of the HC adsorption catalyst 10 can be diagnosed, for example, by calculating the degradation index 2 from a statistical value (an average value or the like) of the gradient 2, and then comparing the degradation index 2 with a diagnosis threshold corrected by taking the operating condition and degradation of the pre-catalyst into consideration.

[0071]   Further, as another degradation index, the degradation of the HC adsorption catalyst 10 can be diagnosed by calculating a degradation index 3 based on the gradient 1 and the gradient 2, and then comparing the degradation index 3 with a diagnosis threshold corrected by taking the operating condition and degradation of the pre-catalyst into consideration. Particularly, since the degradation index 3 is hardly affected by open-air temperature, the diagnosis can be accurately performed by the degradation index 3.

[0072]   Furthermore, although description has been made on the method of calculating only one degradation index and then comparing the degradation index with the diagnosis threshold, the degradation can be judged by calculating a plurality of degradation indexes and then selecting one or more indexes out of the plurality of degradation indexes. For example, when an accelerator is suddenly operated during water evaporation period, the degradation may be judged using the degradation index based on the gradient 2 by inhibiting judgment using the degradation index based on the gradient 1.

[0073]   It can be understood from the above description that the internal combustion engine diagnosis apparatus in accordance with the present invention can diagnose the HC adsorption catalyst from the temperature variation state of the HC adsorption catalyst in the temperature range of 50°C to 250°C during desorbing HC from the HC adsorption catalyst.

[0074]   In other words, by utilizing the heat of reaction of the HC adsorption catalyst at desorbing HC (the heat of reaction is decreased by progress of degradation), the HC cleanup power of the HC adsorption catalyst can be accurately diagnosed, and the diagnosis of the HC adsorption catalyst can be performed without being affected by the degradation state of the cleanup catalyst arranged upstream of the HC adsorption catalyst.

[0075]   The foregoing disclosure has been set forth merely to illustrate the invention and is not intended to be limiting. Since modifications of the disclosed

embodiments incorporating the spirit and substance of the invention may occur to persons skilled in the art, the invention should be construed to include everything within the scope of the appended claims and equivalents thereof.